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# PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

## Improvements in or relating to methods and apparatus for Atomising Liquids

We, ESSO RESEARCH AND ENGINEERING COMPANY, a Corporation duly organised and existing under the laws of the State of Delaware, United States of America, of Elizabeth, New Jersey, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method and apparatus for atomizing liquids. It relates particularly to a method and apparatus for atomizing liquids through the use of sonic energy, and it relates more particularly to such a method and apparatus wherein and whereby the particle size to which the liquid is atomized may be established substantially independently of the wave frequency of the sonic energy.

It is well known in the art that atomization of liquids may be effected through the use of sonic energy. A pertinent reference is the article "Ultrasonic Atomization of Liquids" by J. N. Antonovich appearing at pp. 6—15 of *Transactions on Ultrasonics*, February, 1959, published by the United States Institute of Radio Engineers. One apparatus which has been used for atomizing liquids is a transducer comprising a piece of ceramic piezoelectric material such as barium titanate bonded on a flat surface to the larger diametral surface of a truncated conical resonator of an elastic and electrically conductive material such as aluminum. In a particular apparatus, the ceramic piece is in the form of a disc having two flat, substantially parallel faces. Assuming proper sizing of this assembly, the governing criterion of which will be discussed subsequently, and assuming further that an alternating voltage of relatively high frequency is applied across the flat faces of the ceramic disc, the disc will be cyclically thickened and thinned and will generate alternate compression and rarefaction waves of sonic energy.

This sonic energy, which may be characterized by a frequency above the range of normal hearing, will cause a cyclical lengthening and shortening or longitudinal vibration of the metal resonator attached to the piezoelectric element. With decreasing cross-sectional area of the resonator in the direction away from the ceramic disc or piezoelectric element, there will be a concentration of energy and an increasing amplitude of motion toward the resonator tip. If a drop of liquid such as home heating oil be applied to the resonator tip or to a relatively thin and flexible plate affixed thereto, sonic energy will flow into this drop and the drop will be broken up into a fog of fine particles; that is, it will be atomized.

Determination of the dimensions of the sonic atomizing apparatus will now be considered. In considering this, it should be borne in mind that for a given temperature the speed of sound in a given medium, e.g. solid material, has an essentially fixed value. This speed is the product of frequency and wavelength. Corresponding to an increasing frequency there must be a decreasing wavelength and vice versa. For apparatus of the class described comprising a thin disc of ceramic material bonded to the base of a truncated metal cone, which apparatus may be referred to as being of the half-wave variety, the length of the assembly from the tip of the cone to the more distant face of the ceramic disc should be very nearly equal to one half of the wavelength of sound in the material of the cone at the operating frequency. This assumes that the thickness of the disc is quite small compared to the length of the cone.

It may be seen from this that the higher frequency of sonic energy generated, with resulting reduction in wavelength, the shorter

must be the cone and disc assembly. At increasingly high frequencies this creates problems of fragility of parts in the course of normal mechanical handling, and also of simply having enough cross-sectional area and physical volume of material for energy absorption and transfer purposes. This circumstance is not peculiar to half-wave apparatus only. Similar considerations apply in the design of full-wave sonic apparatus also. In the latter apparatus, a ceramic sleeve or cylinder is bonded at one of its ends to the base of a metal cone. The lengths of the sleeve and cone are each equal to one-half the wavelength of sound in their particular materials at the operating frequency selected. Such apparatus is illustrated and described, for example, in U.S. Patent No. 2,514,080.

Whatever the apparatus used for sonic atomization of liquids, the question of the relation, if any, between the frequency of sonic energy applied and the size of liquid particle generated becomes an important one, assuming a particular particle size is needed or desired, out of consideration of the effect of sonic energy frequency on the dimensions of apparatus elements. To provide a basis for answering this question, some fundamental principles and experimental data relating to the atomization of liquids by sonic energy means will be reviewed.

The mechanism by which direct sonic energy atomization of liquids takes place involves the formation of tiny standing waves at the surface of the liquid. When sonic energy is propagated through a liquid and disturbs its surface, two wave trains are formed at right angles to each other. These trains combine into an interference pattern which comprises many small conical protuberances at the liquid-air interface. If the sonic energy concentration be sufficiently intense, the height of these protuberances will increase to approximately one half of the length of the waves from which they are formed, and droplets or liquid particles will be ejected from their peaks. In this manner, a fog will be formed in the air above the liquid.

Length of surface waves on a liquid being sonically energized is a function of sonic frequency. With increasing frequency, there will be decreasing wavelength. The theoretical relation between wavelength and frequency, also involving density and surface tension of the liquid, developed by Kelvin, Rayleigh and others, is as follows:

$$\text{Wavelength} = \left[\frac{8\pi\ (\text{surface tension})}{(\text{density})\ (\text{frequency})}{}^{2}\right]^{\frac{1}{3}} \quad (1)$$

or, expressing the several factors in their usual symbols:

$$\lambda = \left[\frac{8\pi T}{\rho f^2}\right]^{\frac{1}{3}} \quad (2)$$

Experimental determinations have shown wavelength values calculated according to Equation (2) to be substantially accurate.

Depending on the use to which a liquid broken up or atomized by sonic energy is to be put, for example, a fuel to be mixed with air and then ignited, the particle size to which the liquid is atomized, will be of great importance. For fuel combustion purposes it is desirable that the particles be very fine indeed. Experiments have been conducted to determine a relationship between particle size and surface wavelength on the surface of the sonically energized liquid from which the particles were generated. Determination of such a relationship provides at once, of course, a relationship between sonic energy frequency and particle size by appropriate substitution from Equation (2) above.

In determining the relationship between surface wavelength and/or sonic frequency on the one hand and particle size on the other, sonic energy was applied directly from a transducer assembly to a molten wax for the generation of particles therefrom by spreading or flowing the wax directly onto the resonator tip. These particles were cooled and condensed, and then measured. The wax used for the experiments was "Acrawax C" made by Glyco Products Co., Inc., New York, N.Y. This wax is a synthetic material having an unusually high and well defined melting range of 284—290° F. The specific gravity of this wax, translatable to density, in the temperature range of 310°—350° F. referred to water at 60° F., and its surface tension in this same temperature range are quite close to those of a typical home heating oil at 100° F., the approximate temperature at which an oil of this kind is frequently atomized by traditional means such as a pressure nozzle for mixing with air and subsequent combustion. These properties, important for Equation (2), are compared in Table I below:

TABLE I

| Liquid Properties | Molten Acrawax C | | Typical Heating Oil |
|---|---|---|---|
| Temperature, °F. | 310 | 350 | 100 |
| Specific Gravity (60° F.) | .822 | .811 | .850 |
| Surface Tension, dynes/cm. | 21.7 | 20.1 | 27 |

According to the experiments conducted, fog particle size was found to vary substantially linearly with wavelength. At a frequency of 10 Kcps, the droplets produced were very much larger than those from a conventional oil burner nozzle. At 800 Kcps, however, very fine spherical particles of less than 10 microns diameter were produced. Fuel oil particles of such small size have been shown to burn with a flame essentially the same as that of a fuel gas. Other experimental data relating to sonic energy frequency, surface wavelength, and number median diameter of particles directly generated by sonic energy are given for Acrawax C in Table II below. The number median diameter of particles in microns in the particle size in a population of particles in which 50% of them have a larger diameter and 50% have a smaller diameter, than the median.

TABLE II

| Sonic Energy Frequency, Kcps | Surface Wave-Length, Microns | No. Median Particle Dia., Microns | Ratio Med-. Dia. to Wavelength | 95% are Particles less than, Microns |
|---|---|---|---|---|
| 14 | 147 | 63 | .43 | 140 |
| 130 | 33 | 11 | .33 | 18 |
| 390 | 16 | 6 | .38 | 12 |
| 780 | 9 | 4 | .44 | 8 |

Considering these data together with Equation (2), it may be seen that in view of the substantially linear variation of particle size with surface wavelength, particle size varies also substantially as the negative two thirds power of the sonic energy frequency. In the general qualitative sense, frequency must be increased to obtain a finer size of particle when the liquid to be atomized is disturbed directly by the inflow of sonic energy. With increasing frequency, operating parts become smaller, more fragile, and have less energy absorption and transfer capabilities as pointed out above. Accordingly, for the direct generation of liquid particles by sonic energy means, an effective lower limit will be placed on particle size by the lower limit of size in which the sonic energy transducer can be usefully constructed.

According to this invention, the above-described limitation of the prior art on the degree of fineness to which a liquid may be atomized by sonic energy means is removed by applying such energy to the liquid only indirectly. Specifically, sonic energy is employed to provide mechanical impacting of a flexible screen member on which the liquid to be atomized is coated, flowed, or wiped and from which this liquid is discharged in the form of a fog of fine particles. With the method and apparatus of this invention, the size of particles constituting the fog will be determined primarily by the screen opening size or mesh rather than by the operating frequency of the sonic energy transducer. By a simple changing of screens, particles may be generated through a range of sizes with a single, rather low frequency of sonic energy.

The nature and substance of this invention will be more clearly perceived and fully understood by referring to the following description and claims taken in connection with the accompanying drawings in which:

Figure 1 represents a side elevation view

partly in section of a high frequency electronic generator coupled to a half-wave transducer assembly of a disc piezoelectric element and conical sonic energy resonator in a suitable mounting, a screen being provided closely adjacent the tip end of this resonator according to the present invention and this screen having mounting means whereby its position relative to the transducer assembly may be finely adjusted in at least some directions;

Figure 2 represents a side elevation view partly in section and partly schematic of a portion of an apparatus embodiment of this invention wherein the screen from which liquid particles are discharged is provided with mounting means allowing it to be rotated continuously across the tip of the conical sonic energy resonator for purposes of liquid feeding to this tip;

Figure 3 represents a side elevation view partly in section and partly schematic of a portion of an apparatus embodiment of this invention wherein the screen from which liquid particles are discharged is provided with mounting means allowing it to be translated continuously across the tip of the conical sonic energy resonator for purposes of liquid feeding to this tip;

Figure 4 represents a side elevation view partly in section of a half-wave transducer assembly of a disc piezoelectric element and conical sonic energy resonator with a screen closely adjacent the tip of this resonator according to the present invention, the transducer assembly being provided with an axial passage for purposes of feeding liquid to this tip, and

Figure 5 represents a side elevation view partly in section of a half-wave transducer assembly of a disc piezoelectric element and conical sonic energy resonator with a screen closely adjacent the tip of this resonator according to the present invention, the resonator being provided with connecting radial and axial passages for purposes of feeding liquid to this tip.

Referring now in detail to the drawings, especially to Figure 1 thereof, a high frequency electronic generator 6 having connection to a low frequency voltage source through cable 8 and plug 10 is closely coupled on its output side by means of a cable 12 across the faces of a disc-type piezoelectric element 14 of a sonic energy transducer. This piezoelectric element is bonded to the larger diametral surface of a sonic energy resonator 16 of generally conical form. As assembled, piezoelectric element 14 and resonator 16 should have an over-all length which is essentially equal to one half of the wavelength of sound in the material of the resonator at the operating frequency. A full-wave transducer structure of the kind described already may, however, be used within the scope of the present invention.

For purposes of the present invention, it is not essential that generator 6 be of the electronic variety. This generator may suitably be of the rotary variety also, both varieties and their uses being well known in the sonic energy art. Likewise, the nature of piezoelectric element 14 is not critical. This device may comprise any one of several materials. Use in transducers of such a piezoelectric material as the ceramic crystal barium titanate has been mentioned already. Other ceramic crystal materials suitable for this use include lead zirconates and lead zirconium titanates. Still other materials such as nickel and cobalt-nickel of a magnetostrictive nature may also be used in transducers.

Considering the use of a piezoelectric disc in a transducer assembly for exemplary purposes, however, the disc faces are silvered and then the electrical leads or lugs are soldered thereto. Next the disc must be bonded to the sonic energy resonator cone, and this bond is critical for proper operation of the transducer assembly although neither its structure nor the method of making it constitutes any part of the present invention. In joining the ceramic disc piezoelectric element and the resonator cone, a cement such as an epoxy resin should be used which sets by polymerization rather than by solvent evaporation. A suitable elastic and electrically conductive material for the resonator cone itself is aluminum, as mentioned above. Other materials appropriate for cone 16 include brass and stainless steel. Most desirably the cone will be shaped externally with an exponential curvature, however, the essential requirement is that the tip of the transducer is smaller than its base and it may be, for example, a true cone or even a pyramid.

In the apparatus embodiment of this invention illustrated in Figure 1, support for the transducer assembly is furnished from base element 18. An upwardly-extending post member 20 is threaded into a raised region 22 of base 18, and locked in place with nut 24. At its upper end, this vertical member has a transducer locating ring element 26 threaded thereonto and locked with a nut 28. This ring element encloses the cone of the sonic energy resonator 16. The cone is maintained in spaced relation to ring 26 by means of three point-ended screws such as 30, substantially equally spaced around the ring element, and having lock nuts 32. These screws directed radially inwardly through ring 26 engage notches or drill spots in the lateral surface of the cone. All these spots should lie in a single circumferential line on the cone, and this line should coincide with the node of vibrations in the cone when the transducer assembly is energized from generator 6.

Closely adjacent the tip end of resonator cone 16 is a screen element 34. This screen will actually be in contact with the cone tip intermittently during operation of the trans-

ducer assembly for atomization of liquids according to the present invention, but there is no physical bond between the screen and the cone. Screen 34 may conveniently be of circular form, but is not required to be so configured. As shown, its edge region is slightly upset to fit closely over and extend outwardly along a shaped annular surface of frame member 36. The screen is held tightly on and against frame 36 by means of a clamping ring 38, whereinto are threaded a plurality of thumb screws such as 40 which pass through clear holes in frame 36.

Depending on the materials and dimensions of the parts, for example in the particular apparatus embodiment of this invention as shown in Figure 1, upsetting of the edge region of screen 34 may be effected in a preforming operation, or it may not be effected until the screen is compressed against frame 36 by clamping ring 38. In any case, the screen should be tight over and across the frame when parts are assembled as shown in Figure 1. Holes in the edge region of the screen will preferably be preformed for accommodation of screws 40. The material of screen 34 is not critical for purposes of this invention so long as the screen is characterized by at least a degree of elasticity within a limited range of drum-like flexing. Within the scope of this very general requirement, it may be expected that screens comprising metal wires will be preferable to those comprising threads of either natural or synthetic fibres.

Extending across the lower region of frame 36, and fixedly secured thereto by a plurality of screws such as 42 is a rigid yoke member 44. This yoke is bored vertically to have a hole through which passes the upper threaded end of a post member 46. Yoke 44 is secured on post 46 by means of nuts 48 and 50. The lower end of post 46 is threaded into a sliding block member 52, and is locked therein by means of nut 54. Block 52 is characterized by a guide element 56 formed on or fitted onto its lower surface. This guide element, which may be wedge-shaped in transverse section, fits closely into a groove region 58 formed in base 18. Block 52, guided by element 56 running in groove 58, may slide on surface 60 of base 18. This surface will preferably be smoothly finished as will be the surface of block 52 sliding upon it, and also the bearing surfaces of guide element 56 and groove region 58.

A position-adjusting rod 62 is threaded into block 52, and secured therein by means of nut 64. This rod, threaded at both ends, extends horizontally through a clear hole in raised region 22 of base 18. On its threaded end extending beyond raised base region 22, rod 62 is provided with two wing nuts 66 and 68, the first of these being intended to bear against a lateral preferably smoothly finished surface 70 of raised base region 22, and the second being intended to bear and lock against the first. A compression spring 72 encloses adjusting rod 62, and is contained between sliding block 52 and raised base region 22. The force of spring 72 acting against block 52 tends to move this block in a direction carrying screen 34 away from the tip end of sonic energy resonator 16.

The remaining structural item appearing in Figure 1 is feed tube 74 through which liquid to be atomized is flowed onto screen 34. This tube has connections not shown leading to a source of liquid, a tank of home heating oil for example, these connections including appropriate pumping and metering devices. The mounting of feed tube 74 will be capable of movement so that this tube may be moved not only simultaneously with screen 34 as sliding block 52 is shifted, but also, desirably, independently of screen 34 to allow adjustment of position of the tube outlet end with respect to the screen. It is within the scope of the present invention that the liquid feed tube be positioned to flow liquid onto that side of the screen whereto the tip of the sonic energy resonator cone is more closely adjacent, as well as onto the more distant side. A feed tube 74[1] so positioned is indicated in dotted outline. Tubes 74 and 74[1] may be provided with wide-mouthed outlet ends to achieve good initial distribution of liquid across screen 34.

Although the machine elements which would be involved are not specifically illustrated, it is obviously within the scope of well known art that means for recovering liquid material flowed onto but not atomized from screen 34 could be provided. Such means might include, for example, a drip pan located below the screen and a scraper operating across one or both faces of the screen.

Adjustment and operation of the apparatus shown in Figure 1 will now be considered. Locking wing nut 68 is backed off from adjusting wing nut 66, and the latter nut is manipulated to shift sliding block 52 as necessary to bring screen 34 into at least light contact with the tip end of the cone of the sonic energy resonator 16. Nuts 48 and 50 may be manipulated to shift yoke 44 up or down on post 46, and so adjust the vertical position of screen 34 with respect to the cone. The most desirable vertical adjustment will be determined by experience, but as a starting adjustment the screen may be approximately centered up and down with respect to the cone, substantially as shown. Although no means of making transverse adjustment of the screen are particularly illustrated, it is obvious that such means could be provided easily if desired. However, if such means be not provided, satisfactory results will be achieved within the scope of other adjustments if the illustrated parts are so designed that screen 34 is centered transversely with respect to the cone of resonator 16.

Screen 34 having been positioned with respect to the cone of resonator 16, liquid feed tube 74 is position with respect to the screen. An initial quantity of liquid to be atomized may be flowed onto the screen, enough at least to provide some liquid on that part of the screen in front of the tip of the sonic energy resonator cone. The next step will be to start the generator 6 according to procedures appropriate to that piece of equipment depending upon its particular design. Such procedures do not constitute any part of the present invention. With generator 6 imposing an alternating voltage across the faces of piezoelectric element 14, there will be a flow of sonic energy into the resonator cone. Physically, this flow will be evidenced by a rapid, though relatively minute shortening and lengthening of the cone. Actual movement of any region of the cone will be greatest at the tip adjacent screen 34.

The nature of the interaction between the resonator cone tip of the transducer assembly and the screen is primarily one of the tip impacting upon the screen in the lengthening portion of the vibrator cycle of the transducer. Even though the screen be rather heavily tensioned initially across the cone tip by adjustment of block 52, its inertia will be such that it cannot follow fully the linear excursions of this tip at sonic or ultrasonic frequencies. In the shortening portion of the vibratory cycle of transducer, the tip of the resonator cone will pull back out of contact with screen 34 even though the screen flexes elastically to try to follow it, and then as the transducer goes into the lengthening portion of its vibratory cycle the cone tip will drive against the screen to distend it to the right according to the structural arrangements of Figure 1. It will be seen that in the course of operation of the illustrated apparatus contact between the transducer and the screen, specifically between the resonator cone tip of the transducer assembly and the screen, exists only intermittently.

The foregoing-described impact action of the tip of the cone of the resonator 16 upon screen 34 will cause atomization of liquid on that part of the screen generally adjacent the tip region of the cone, and will further cause at least some net displacement discharge of this liquid from the screen as a particle fog 76. Once atomization has been started, continuous metered feeding of liquid through tube 74 onto screen 34 may be commenced for flow downward onto the screen area in way of of the tip of the cone. Wing nut 66 may be manipulated for fine adjustment of the screen longitudinally with respect to the cone for optimum results. This nut should be locked with wing nut 68 once such adjustment has been achieved.

Operating results obtained with an apparatus embodiment of this invention essentially similar to that shown in Figure 1 using molten Acrawax C as the liquid to be atomized are given in Table III below:

TABLE III

| Screen Opening, Microns | Operating Frequency, Kcps | Mass Median Particle Dia., Microns* | Approx. Operating Frequency for same Automization without Screen, Microns |
|---|---|---|---|
| No screen | 15 | 112 | 15 |
| 177 | 15 | 116 | 14 |
| 149 | 15 | 100 | 18 |
| 105 | 15 | 80 | 25 |
| 53 | 15 | 63 | 37 |
| 38 | 15 | 31 | 100 |

* The mass median diameter of particles is the diameter of particles in a population of particles in which 50 wt. % of the particles have a larger diameter and 50 wt. % have a smaller diameter, than the median.

In evaluating these results, it should be observed first of all that a constant operating frequency of 15 Kcps was employed. The condition which was varied was the screening of the sonic energy resonator cone. For a first trial no screen was used at all. This yielded particles of a mass median diameter of 112 microns. Note that particle size designation according to mass median diameter in Table III differs from designation according to number median in

Table II, mass median tending to give significantly higher values. For a second trial, a screen with comparatively coarse openings of 177 microns was used. This yielded particles of a mass median diameter of 116 micons, essentially the same as that obtained without any screen within experimental error. For a third trial, a screen with openings of 149 microns was used. This yielded particles of a mass median diameter of 100 microns, definitely smaller than that obtained without any screen. In succeeding trials, screens having openings of 105, 53 and 38 microns were used. These yielded particles of succeedingly smaller mass median diameters of 80, 63, and 31 microns.

With particle size data available from experimental trials using screens, calculations were made on the basis of the relationship developed from Table II of this specification to determine the operating frequency needed to yield these same particle sizes in the absence of any screening. The results of these calculations are given in the fourth column of Table III. To cite one example for purposes of comparison, it may be seen that for direct, unscreened atomization of molten Acrawax C, an operating frequency of 100 Kcps would be required to yield particles as fine as those obtainable using a frequency of only 15 Kcps and a screen with openings of 38 microns. From what has been pointed out already, the advantages of being able to use the lower frequency to achieve the same degree of atomization are apparent.

Referring next to Figure 2, a screen 78 is stretched across and retained on a frame 80 by means of a clamping ring 82 and a plurality of thumb screws 84. On its outer circumferential surface, frame 80 is fixedly fitted within the inner race of a ball bearing assembly 86. The outer race of this assembly is in turn secured to relatively rigid framework structure such as that of an oil burner, indicated generally as 88. The inner circumferential surface of frame 80 is hobbed or otherwise machined to provide a complete annulus of gear teeth. These teeth are meshed with those of a pinion 90 fixedly mounted on a shaft 92 which is supported in suitable bearings not shown. Shaft 92 is operatively connected to an electric motor 94 or other suitable driving means which is shown essentially schematically, but which will in fact be supported on or from a rigid structure such as 88. When motor 94 is energized to turn shaft 92 and pinion 90, the meshed connection between the teeth of the pinion and those of frame 80 will cause rotation of the frame and also of screen 78 mounted on it.

The tip of a conical sonic energy resonator 96 which is part of a transducer assembly not fully shown is positioned in intermittently contacting relation to screen 78, just as, with one limitation, the tip of resonator 16 of Figure 1 is or may be positioned with respect to screen 34. This limitation is that resonator 96 may not be axially aligned with the center of screen 78, but must be at least somewhat offset therefrom so that as frame 80 and screen 78 are turned by motor 94 there will be a sweep of screen material past the tip of the resonator. The initial rubbing pressure between screen 78 and the cone of resonator 96 may be adjusted by shifting the mounting of the transducer assembly, for example. This mounting is not specifically illustrated, but it should provide support for the assembly according to the principle mentioned and illustrated already, that is, essentially point support at the nodal cross-section.

Also offset from the center of screen 78 at a radius essentially the same as the offset of the cone of resonator 96 is a means whereby liquid to be atomized may be applied continuously to the screen. In its illustrated embodiment, this means comprises a wick or porous wiper 98 maintained in contacting relation with screen 78 by a holder 100. This wick is saturated and steadily supplied with liquid from a source not shown as indicated by an arrow. As screen 78 is turned by motor 94 and at least part of it rubs across wick 98, it will pick up liquid from the wick. This liquid will be carried around in front of the tip of the cone of resonator 98, and there discharged as a fog of fine particles 102 assuming that sonic energy is flowing into the resonator from a piezo-electric element not shown. It is to be understood that in place of wick 98 a continuously moistened brush, a spray nozzle, or indeed any convenient and suitable means for applying liquid to screen 78 at the required radius may be used. This means may apply the liquid onto the rear side of the screen just as tube 74[1] does on screen 34 shown in Figure 1. Suitable screen scraping and drip collecting means may be provided for the recovery of liquid applied to the screen by wick 98 or its equivalent, and not subsequently atomized therefrom.

Referring next to Figure 3, a screen 104 in the form of an endless belt having a regular series of perforations along each of its edges is passed over and retained on four double sprocket wheel assemblies 106, 108, 110, and 112. These assemblies will all be rotatably secured in some relatively rigid framework structure, such as that of an oil burner, which is not specifically illustrated. At least one of the sprocket wheel assemblies will preferably have a capability for adjustment provided in its immediate mounting so that it may be shifted in position for purposes of screen removal, replacement, and tensioning. As illustrated, sprocket wheel assembly 106 is operatively connected to an electric motor 114 or other suitable driving means which is shown essentially schematically, but which will in fact be supported on or from a rigid structure such as that of the oil burner mentioned above. In

respect of the screen, sprocket wheel assembly 106 is a driving means or driver. The other sprocket wheel assemblies, 108, 110, and 112, are all driven by screen 104 passing over them as this screen is itself driven by action of motor 114 imposing rotation on sprocket assembly 106.

A transducer assembly comprising disc-type piezoelectric element 116 and conical sonic energy resonator 118 is positioned within the region bounded by screen 104, with the tip of the resonator being in intermittently contacting relation to screen 104, in the run of this screen between driven sprocket assembly 112 and driver sprocket assembly 106 to insure tautness of the screen material passing in front of the resonator cone tip. The initial rubbing pressure between screen 104 and resonator 118 may be adjusted by shifting the mounting of the transducer assembly, for example. This mounting it not specifically illustrated, but it should provide support for the assembly according to the principle mentioned and illustrated already, that is, essentially point support at the nodal cross-section.

Also located adjacent screen 104 is a means whereby liquid to be atomized may be continuously applied to the screen. In its illustrated embodiment, this means comprises a wick or porous wiper 120 maintained in contacting relation with screen 104 by a holder 122. This wick is saturated and steadily supplied with liquid from a source not shown as indicated by an arrow. As screen 104 is turned by motor 114 and at least part of it rubs across wick 120, it will pick up liquid from the wick. This liquid will be conveyed in front of the tip of resonator cone 118, and there discharged as a fog of fine particles 124 assuming that sonic or ultrasonic energy is flowing into the resonator from piezoelectric element 116 which is in turn energized from an alternating voltage source not shown.

It is to be understood that in place of wick 98 a continuously moistened brush, a spray nozzle, or indeed any convenient and suitable means for applying liquid to screen 104 may be used. This means may apply the liquid onto the side of the screen more closely adjacent the tip of resonator cone 118 just as tube 74[1] does on screen 34 shown in Figure 1. Preferably the liquid applying means will be located adjacent the run of screen 104 between driven sprocket assembly 112 and driver sprocket assembly 106, and above resonator cone 118. With this arrangement, the one which is illustrated, liquid from the feeding means will have to travel only a relatively short distance from the point of its application onto the screen to that of its atomization therefrom. With this arrangement also, liquid will not be intentionally carried around any of the sprocket assemblies or other screen driving or driven devices which may be used. It is obvious that the liquid applying means must be in transverse alignment with the transducer assembly. It is further obvious that suitable screen scraping and drip collecting means may be provided for the recovery of liquid applied to the screen by wick 120 or its equivalent, and not subsequently atomized therefrom.

Referring next to Figure 4, a transducer assembly comprising disc-type piezoelectric element 126 and conical sonic energy resonator 128 is positioned to bring the tip of the resonator into intermittently contacting relation to a partially illustrated screen 130. This screen may be taken as configured and mounted similarly to screen 34 of Figure 1. The assembly of piezoelectric element 126 and resonator 128 may likewise be taken as mounted similarly to the assembly of piezoelectric element 14 and resonator 16 of that same Figure. The transducer assembly of Figure 4 is characterized by an axial hole 132 extending for the full length of the assembly. At its end opening through the piezoelectric element, this hole is provided with a sleeve fitting 134 whereonto a liquid feed tube 136 is attached. The attachment of fitting 134 on and in piezoelectric element 126 may be effected with an epoxy resin, similarly to the attachment of the piezo-electric element onto resonator 128.

Liquid to be atomized is supplied steadily to tube 136 at an appropriately regulated rate from a source not shown, as indicated by an arrow. Leaving this tube, the liquid flows through fitting 134 and hole 132 out to the region of screen 130 which is generally adjacent the tip of the cone of the resonator 128. From there the liquid will be discharged as a fog of fine particles 138, assuming that sonic energy is flowing into the resonator from piezoelectric element 126 which is energized in turn from an alternating voltage source not shown.

Referring finally to Figure 5, a transducer assembly comprising disc-type piezoelectric element 140 and conical sonic energy resonator 142 is positioned to bring the tip of the resonator into intermittently contacting relation to a partially illustrated screen 144. This screen may be taken as configured and mounted similarly to screen 34 of Figure 1. The assembly of piezoelectric element 140 and resonator 142 may likewise be taken as mounted similarly to the assembly of piezoelectric element 14 and resonator 16 of that same Figure. The transducer assembly of Figure 5 is characterized by an axial hole 146 in the cone of the resonator 142 extending back from the tip thereof to essentially the nodal cross-section of this cone. At this cross-section, axial hole 146 is joined by at least one radical hole 148 extending outwardly to the surface of the cone. At its end opening through resonator 142, radial hole 148 is provided with a sleeve fitting 150 whereonto a liquid feed tube 152 is attached. The attachment of fitting 150 on and in resonator 142 may be effected with an epoxy resin similarly to the attachment of transducer

140 on the resonator, or by any other suitable metal joining means such as a screwed joint.

Liquid to be atomized is supplied steadily to tube 152 at an appropriately regulated rate from a source not shown, as indicated by an arrow. Leaving this tube, the liquid flows through fitting 150, radial hole 148, and axial hole 146 out to the region of screen 144 which is generally adjacent the tip of the cone of the resonator 142. From there the liquid will be discharged as a fog of fine particles 154, assuming that sonic energy is flowing into the resonator cone from piezoelectric element 140 which is energized in turn from an alternating voltage source not shown.

Although this invention has been described with a certain degree of particularity, it is to be understood that the present disclosure has been made only by way of example, and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the scope of this invention as hereinafter claimed. It is to be understood particularly that whereas this disclosure has been generally in terms of sonic energy vaporizing apparatus operating at a fundamental harmonic frequency to create a single nodal point or cross-section therein, such apparatus may be operated at higher harmonic frequencies and this invention still retain its full utility therewith. It is to be understood more particularly that for purposes of this invention the structural element described herein as a "screen" is not restricted to structures comprising a mesh of threads, wires, or other filament members, but is inclusive of perforated sheets, and any other areawise-discontinuous structures suitable for use. It is to be understood still more particularly that sonic energy resonator elements of other than conical form, for example, of the form of a stepped cylinder, may be used. It is to be understood even still more particularly that the piezoelectric and resonator elements which the transducer comprises may be bonded in energy-transmitting relation by mechanical clamping rather than by the use of a cement.

WHAT WE CLAIM IS:—

1. A method for atomizing liquids, said method comprising the steps of (1) intermittently impacting at least a part of a flexible screen member by the application of sonic energy thereto, and (2) applying liquid to be atomized onto that part of said screen member being impacted.

2. A method for atomizing liquids, said method comprising the steps of (1) intermittently impacting sequential parts of a moving, flexible screen member by the application of sonic energy thereto, and (2) applying liquid to be atomized onto those parts of said screen member being impacted.

3. A method for atomizing liquids according to Claim 2 in which said screen member is moving in continuous rotation.

4. A method for atomizing liquids according to Claim 2 in which said screen member is moving in continuous translation.

5. An apparatus for atomizing liquids, said apparatus comprising (1) a transducer capable of receiving inputs of alternating voltage and providing outputs of vibratory mechanical displacement at a localized region of its structure, (2) a screen member extending generally perpendicularly to the direction of said output displacement liquid feeding means in operative relation to said screen member for applying liquid to be atomized thereonto, and (3) structural support means for said screen member independent of said transducer whereby at least a part of said screen member is maintained in contact with said localized region of said transducer when said transducer is not providing outputs of vibratory mechanical displacement.

6. An apparatus for atomizing liquids according to Claim 5 in which said transducer is characterized by a base end removed from said localized region, a tip end at said localized region, a longitudinal axis essentially perpendicular to both said base and tip ends, and a through-going axial hole in said longitudinal axis.

7. An apparatus for atomizing liquids according to Claim 6 which includes liquid feeding means for flowing liquid to be atomized into said transducer at the end of said through-going axial hole opening through the base end of said transducer.

8. An apparatus for atomizing liquids according to Claims 6 or 7 in which said transducer is characterized by a base end removed from said localized region, a tip end at said localized region, a lateral surface, an axis essentially perpendicular to both said base and tip ends, a nodal plane of longitudinal vibrations intermediate said base and tip ends, and an open-ended hole radial to said longitudinal axial hole extending from said lateral surface in essentially said nodal plane and connecting with said longitudinal axial hole.

9. An apparatus for atomizing liquids, according to any of claims 5—8 having structural support means for said transducer, structural support means for said screen member maintained in spaced relation to said support means for said transducer, and adjusting means cooperatively joining both said support means whereby said spaced relation may be regulated for adjustment of the pressure at which said part of said screen member is maintained in contact with said localized region of said transducer when said transducer is not providing outputs of vibratory mechanical displacement.

10. An apparatus for atomizing liquids, according to any of claims 5 to 9 wherein said structural support means for said screen member is adapted to permit rotation of said screen member with respect to said transducer about

an axis essentially parallel with the axis of said transducer but offset therefrom.

11. An apparatus for atomizing liquids according to Claim 10 which includes drive means operatively connected with said support means whereby and wherethrough said screen member may be rotated.

12. An apparatus for atomizing liquids, according to any of Claims 5 to 11 wherein said screen support means is adapted to permit translation of said screen member across the tip end of said transducer.

13. An apparatus for atomizing liquids according to Claim 12 in which said screen member is configured as an endless belt.

14. A method of atomizing liquids as claimed in Claim 1 and substantially as described herein and illustrated in the drawings.

15. Apparatus for atomising liquids substantially as described herein and illustrated in the drawings.

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COMPLETE SPECIFICATION

2 SHEETS

This drawing is a reproduction of the Original on a reduced scale.

SHEET 1

FIG.1.

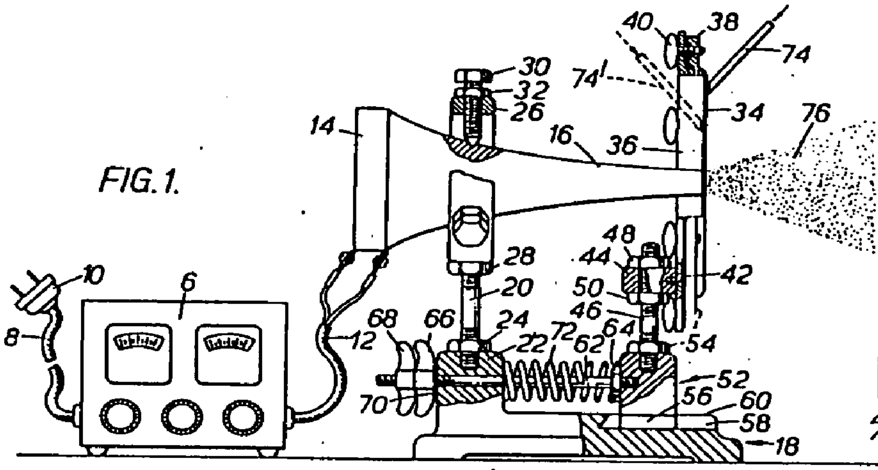


FIG.2.

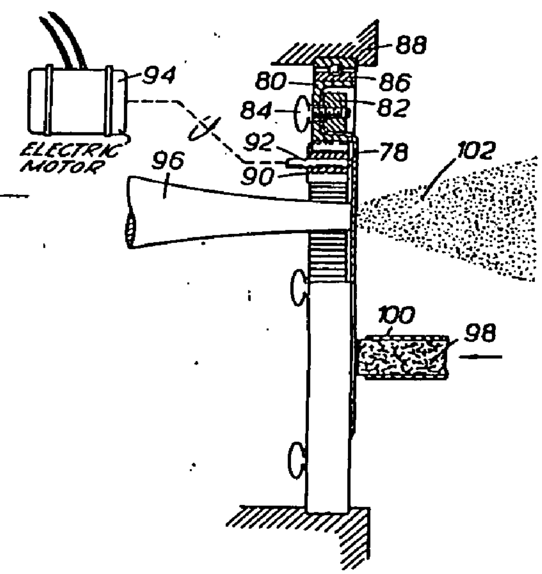


FIG.3.

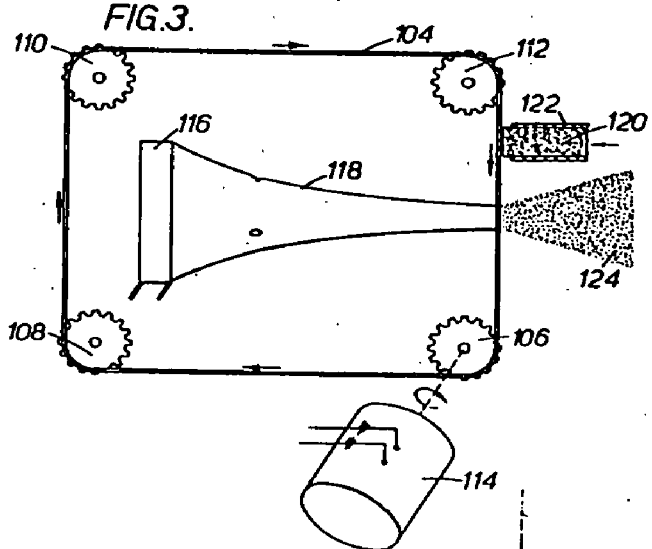

FIG. 4.

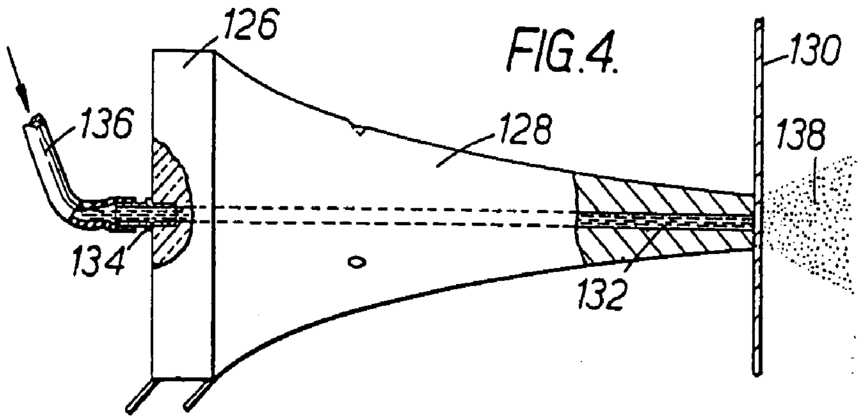


FIG. 5.